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Creating Tankwars III: The Multiple-Weapon, Burst-Fire Combat Version

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This report describes the latest version of Tankwars—Tankwars III—the multiple-weapon, burst-fire version and its verification. Tankwars, created by Fred Bunn of the U.S. Army Research Laboratory, is a FORTRAN program that models small unit armored warfare. The model represents armor system operations and its sensing and firing interaction with other armor systems. Tankwars' basic use is pitting two vehicle types against each other in many battles to see which side does better. Tankwars has three versions: Tankwars I, the original; Tankwars II, the sustained combat model; and now, Tankwars III, the multiple-weapon platform, burst-fire model. Tankwars II models single weapon armored vehicles. However, a need to simulate infantry fighting vehicles fighting other infantry fighting vehicles exists. These vehicles can engage each other with either missile or automatic cannon weapon systems. Thus, there is a need for multiple-weapon, burst-fire combat simulation capability, and Tankwars III meets the need. The basic additions to the Tankwars II model are weapon selection, action when no weapon is available, and burst fire. Also, the existing submodels of target selection; surviving vehicle ammunition count; and burst-fire action, accuracy, and vulnerability were altered.

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EXECUTIVE SUMMARY

The latest version of Tankwars—Tankwars III—the multiple-weapon, burst-fire version—has been created. Tankwars, created by Fred Bunn of the U.S. Army Research Laboratory (ARL), is a FORTRAN program that models small unit armored warfare. A small unit is defined as being between 1 to 20 vehicles. The model represents armor system operations and its sensing and firing interaction with other armor systems. Tankwars' basic use is pitting several vehicles of one type against several vehicles of another type in many battles to see which side does better.

Tankwars has three versions: Tankwars I, the original; Tankwars II, the sustained combat model; and now, Tankwars III, the multiple-weapon platform, burst-fire model. Tankwars II models single-weapon armored vehicles. However, a need to simulate infantry fighting vehicles engaging other infantry fighting vehicles exists. These vehicles can engage each other with either missile or automatic cannon weapon systems. Thus, there is a need for multiple-weapon, burst-fire combat simulation capability, and Tankwars III meets the need. The basic additions to the Tankwars II model are weapon selection, action when no weapon is available, and burst fire. Also, the existing submodels of target selection; surviving vehicle ammunition count; and burst-fire action, accuracy, and vulnerability were altered.

The newer version's verification was done in two parts. The first part was getting an exact match between Tankwars II and Tankwars III for single-weapon, nonburst-fire combat. The second part was checking that Tankwars III gave expected results in multiple-weapon, burst-fire combat. In matching the newer and older versions, several bugs were found in the older version; these bugs were corrected. Tankwars II and III matched exactly in events and summaries for 1,000 Monte Carlo repetitions for all scenario variations played. In multiple-weapon, burst-fire combat, Tankwars III gave expected results. With the same number of identical vehicles on each side, neither side did better than the other for the meeting engagements. For attacking and defending scenarios, red vs. blue gave similar statistics as blue vs. red. Also, a force of vehicles with two weapons did better, with some exceptions, than the same force of vehicles with a single weapon. Most exceptions were attributable to a weak primary weapon compared to the secondary weapon. Thus, the author believes the model is verified as reasonable.

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1. INTRODUCTION

The need for a version of Tankwars that simulates multiple weapons on a platform and burst fire was met. Tankwars, created by Fred Bunn of the U.S. Army Research Laboratory (ARL), is a FORTRAN program that models combat between forces of identical single-weapon armored vehicles. However, a need to simulate infantry fighting vehicles engaging other infantry fighting vehicles exists, and the new Tankwars III fills the need. The new version allows a platform with multiple main weapons to be played in a Tankwars-like battle. The basic additions to the Tankwars model are weapon selection, action when no weapon is available, and burst fire. Also, the existing submodels of target selection, surviving vehicle ammunition count, and burst-fire action, accuracy, and vulnerability were altered. This report describes the Tankwars model, discusses the need for modeling multiple weapons on a platform, describes the additions to and modifications of the model, and describes the verification study. Throughout this report, the term "tank" means any weapon system platform.

2. TANKWARS INTRODUCTION

Tankwars models the operation of an armored system and its engagement of other armored systems. All vehicles of one side (called red or blue) are identical, and each has a single weapon. These forces are pitted against each other, and the battle interactions are printed. Tankwars' output is win percentage and exchange ratio, among other statistics. Tankwars is used to evaluate the effectiveness of technologies in armor operations. Some examples of studies done with Tankwars are evaluation of the 120-mm gun vs. the 105-mm gun, helicopters with STAFF rounds vs. tanks, particle beams vs. cannons, and shoot-until-kill vs. shoot-until-hit tactics. These examples demonstrate Tankwars' versatility.

The Tankwars program is event driven; that is, events are scheduled and added to a queue and then are called at the time they are scheduled, unless they are canceled by another event. Being Monte Carlo in nature, the program runs a battle many times, drawing new values for the random variables in the model. This allows for a generalization of the individual battles.

Vehicle fire and movement in Tankwars will now be explained. Initially, the attacking tanks set up on a line parallel to the line of defending tanks. Attacking tanks each move independently along their predetermined paths, attempting to kill all the defending tanks. The defending tanks are in hull defilade and attempt to kill all the attacking tanks. The orientation of a tank's hull and turret relative to the line

of its enemy is assumed to have a cardioid distribution. As the attacking tanks move along the path, they will enter zones where they will be visible or invisible to everyone. This simulates loss of line-of-sight because of terrain. However, if smoke is being played, loss of line-of-sight is determined for each pair of tanks. If attacking tanks have a halt-to-fire system, they will slow down and stop to fire and then continue to close in. Figure 1 depicts the attackers' paths and visibility segments and the defenders' line of defense.

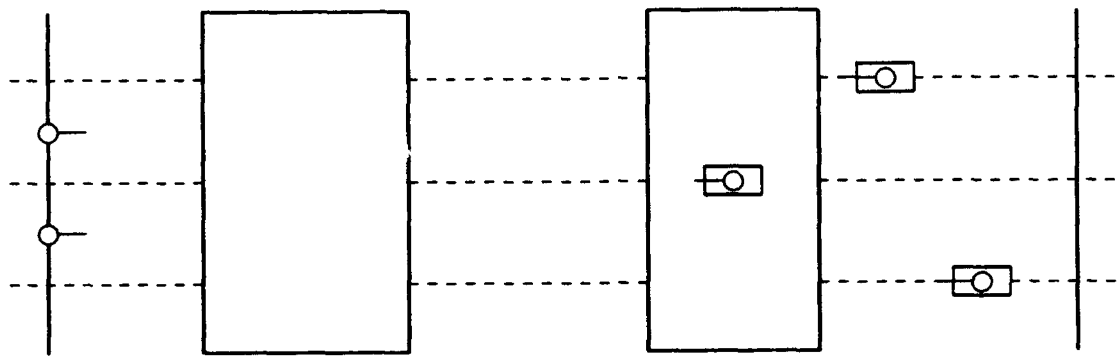

Figure 1. Intervisibility segments along paths of attackers in tankwars.

The right-most vertical line of Figure 1 represents the attacker's line of departure. Each of the three horizontal, parallel lines represents an attacker's typical path, and the boxes represent the areas where terrain block the line-of-sight. The left-most vertical line represents the defenders' line of defense. The defenders are in hull defilade as represented by only the gun turrets being shown. As the attackers move along, there will be exchanges of fire. All the tanks will be doing a firing sequence of search, detect, acquire, fire, impact, and damage, and then either reengage or disengage unless interrupted by some event such as being hit. Defending missile platforms will go behind terrain to reload if necessary.

Blue combatants can start with a full ammunition load or start with the ammunition left from a previous battle. Fighting "in waves" is the Tankwars term for fighting without ammunition resupply. Battles fought in waves can be considered to be simultaneous battles along the front. The blue army

gathers the surviving tanks of a wave with enough ammunition for another battle and allocates these tanks to the battles of the next wave. The user specifies the number of battles in a wave and the number of waves. The user also specifies the scenarios (red attack, blue attack, meeting engagement) and the battles' opening ranges. Specifying a number of battles for a number of waves for a number of starting ranges for all the scenarios can lead to an overwhelming number of program runs.

3. NEED FOR TANKWARS III

For studies of the type conducted earlier, no need existed for a multiple-weapons platform model. For a tank vs. tank scenario, only the main armament would be used. For a tank vs. an infantry fighting vehicle (IFV) scenario, the assumption was that the tank would only use its cannon and the IFV would only use its missiles. We now need to model IFVs fighting IFVs. Both cannon and missile systems can be used to kill an IFV, thus, the need for a multiple-weapons model of armor warfare.

4. CHANGES IN TANKWARS MODEL

The changes made in the Tankwars model involved assumptions, additions, and modifications. One assumption made was that each weapon platform uses a common optical/infrared sensor; hence, only one weapon fires at a time. The additions were weapon selection, contingency plans if no weapon was selected, and burst fire. Finally, modifications were needed because of the additions.

In weapon selection, the weapons are listed in priority. The weapon selection model chooses the primary weapon if it has ammunition and the target is within weapon range. If not, then the secondary weapon is chosen if the same conditions are met. If not, then the tertiary weapon is chosen, and so forth. All weapons on a platform should be able to damage vehicles of the enemy. The following is the pseudo-code used for the weapon selection.

```
for each weapon of the army of the firer, in order of priority
    if (target in range window of weapon and weapon has ammo) then
        select the weapon;
        stop searching for weapon to use;
```

If no weapon is selected, then a list of contingency plans is used. If no weapon is chosen for lack of ammunition, then both defenders and attackers hide. If no weapon is chosen for lack of range, then

defenders wait for the attackers to approach, and attackers close in. The following is the pseudo-code for the algorithm.

```
for each weapon of the army of the firer
    if (weapon has ammo and range to target greater than range of weapon) then
        declare firer will have weapon available in the future;
if firer will have weapon available in the future then
    if firer is an attacker then
        cancel current motion and schedule an acceleration;
else
    schedule a hide;
```

Burst fire was the last addition to the model. Tankwars II has an incomplete burst-fire submodel. That submodel was redone and finished. Basically, the submodel schedules the firing of a round if it is not the last round of a burst; otherwise, the firer is reengaged or disengaged from the target, depending on the firing tactic. The pseudo code follows.

```
if the weapon has ammunition then
    if this round was not last round in burst then
        schedule fire of next round of burst;
    else
        reset number of rounds in burst;
        if (switch after one burst OR switch after certain number of bursts and that number of bursts have been made)
            disengage from target;
            if firer does not have a halt-to-fire system and can move then
                schedule acceleration;
            reset number of shots (bursts) by firer on target;
        else
            calculate time until next burst;
            schedule next burst;
else
    if firer can go then
        schedule an acceleration;
        schedule a hide;
```

Burst fire requires accuracy and vulnerability submodels that differ from single-shot accuracy and vulnerability. The burst-accuracy submodel was derived by looking at the burst-accuracy data provided by the U.S. Army Materiel Systems Analysis Activity (AMSAA). These data are the standard deviations of the burst-to-burst and within-burst errors in both the vertical and horizontal components for various ranges. The burst-accuracy submodel finds the location of impact, relative to the aim point, by summing the draws from the burst-to-burst and within-burst error distributions. The mathematical description of the model follows.

$TE(x) = BB(x) + WB(x)$
$TE(y) = BB(y) + WB(y)$

TE(x), TE(y) - coordinate of impact relative to aim point
BB(x), BB(y) - draw from burst-to-burst error distribution (drawn at beginning of each burst)
WB(x), WB(y) - draw from within-burst error distribution (drawn for each round in burst)

$BB(x) \sim N(0,S[BB(x)]),\ BB(y) \sim N(0,S[BB(y)]),$
$WB(x) \sim N(0,S[WB(x)]),\ WB(y) \sim N(0,S[WB(y)]),$

$S[BB(x)],\ S[BB(y)],\ S[WB(x)],\ S[WB(y)]$ *- respective standard deviations of the error distributions.*

The data are available for a stationary firer vs. a stationary target and for a stationary fire vs. a moving target for certain weapon systems.

Unfortunately, vulnerability data that include synergistic effects for multiple hits in a burst are not available because of the cost of finding such complex information. Thus, the burst vulnerability submodel in Tankwars III treats any hit on a tank as having the effect of a first hit on an undamaged tank. This means that the model underestimates the lethality of a weapon or overestimates the survivability of a target.

Adding multiple weapons and burst fire made other modifications necessary. Changes were made in the way tanks select targets and fire and the way ammunition on surviving tanks is counted. In target selection, some weapon must be available before scheduling a target select. In counting the remaining rounds left on board a surviving tank, the number of shots left are counted instead of the number of rounds. A shot is the firing of a missile, a large cannon round, or a burst of an automatic cannon. Finally, the fire submodel was changed. Attempts at pinpointing a flash now occur only at the start of a burst, and the number of shots on a target is now incremented only at the end of a burst. The round-count reset in a burst was moved from the fire submodel to the burst-fire submodel. Target range calculation and new round-attribute assignments were moved to a round-creation submodel. Lastly, the logic of finding and scheduling of round effects was streamlined. The following is the pseudo code for the modified fire submodel.

```
declare firer not to be busy;
increment number of rounds used;
if burst fire then
    increment number of rounds in burst;
else
    declare round to be first round in burst;
if not within a burst then
```

```
    increment the number of shots on the target;
if the target is real then
    record the time for fire at this target;
record the time of this fire;
if this is the first round in the burst then
    find who saw the flash of the round;
if the firer is not a flashing decoy then
    create a round;
    schedule impact of round;
    if the round is a missile then
        declare that firer has a missile on the target;
        find a guidance channel for the missile;
        if there is a channel for the missile then
            determine/schedule action of firer after it has fired missile;
    else if the round is KE, HEAT, or STAFF then
        if the shot consists of a single round then
            determine/schedule action of firer after is has fired single round;
        else
            determine/schedule action of firer after burst;
    else
        stop;
```

This concludes the alterations to the Tankwars model.

5. CODE MODIFICATIONS

The code revisions include format improvements and additional submodels. The format improvements make the program easier to understand and debug. The additional submodels allow the program to simulate burst fire and multiple weapons on a firing platform.

The format changes are as follow:

1. All variables are now declared. This makes it possible for the compiler to print undeclared variables; these are generally misspelled.
2. All branches and loops are now consistently indented to improve readability.
3. Capitalization was used to clarify the meaning of strings as follows:
   a. Local variables, reserved works, and subroutines are in lower case. Subroutines can be distinguished by the reserved word *call* preceding them, and local variables can be distinguished in that they cannot be reserved words.
   b. Common block variables begin with an upper case letter.
   c. Functions and parameters are all upper case. Functions can be distinguished since they are followed by parentheses.

4. All common block variables are in *include* files. This guarantees the consistency of the common blocks in different routines.
5. The print statements that generate the event history now use a uniform format. This simplifies the debugging programs that examine the output.
6. Some constants have been replaced by parameters to add mnemonic meaning.
7. All routines now contain trace statements to aid debugging. This made it possible to show that Tankwars II and Tankwars III called routines in exactly the same sequence.
8. The code that assigns a missile guidance channel is now in a separate routine.
9. The code that finds whether firer i is guiding a missile to target j is now in a separate routine.

Coding changes to simulate burst fire and multiple weapons on a firing platform are as follow:

1. The dimensions of several blocks of variables were increased to include the weapon number. This was done for both data and status variables.
2. The event history format was changed to include the number of the weapons being used for the event.
3. New variables were created to
   a. represent the number of weapons on a platform,
   b. represent the weapon in use by a tank,
   c. represent the minimum and maximum range of the weapons (used by the weapon selection routine to determine availability of weapons),
   d. keep track of where in the burst the particular round of the burst is, and
   e. keep track of whether a firer had pinpointed a target. (Keeping a record of whether a firer pinpointed a target is important because in Tankwars III, the weapon to be used has not yet been determined at the time the select start routine is called. Therefore, the decision to increment the number of channels if a missile system is being used cannot be made yet. After target selection, if a missile system is indeed chosen, then the number of its channels in use is incremented).
4. New routines were created, and old routines were modified.
   a. Routines were created to implement the new submodels of weapon selection, no-weapon-available contingency plans, and burst fire.
   b. The code for the fire routine was rewritten to reflect its reorganization.
   c. A function to determine what weapon is in use by a firer was created.

This summarizes the coding changes that were made to turn Tankwars II into Tankwars III.

6. VERIFICATION STUDY

This section describes the methods used and the results obtained in verifying Tankwars III. The two parts of the verification study were as follow:

1. An exact match between the Tankwars II and Tankwars III for the single weapon, nonburst-fire combat.
2. Checking for expected results from Tankwars III in multiple-weapon, burst-fire combat.

The vehicles simulated were the Bradley fighting vehicle (BFV) for the blue side and a Russian infantry fighting vehicle (IFV), the BMP-1, for the red side. Modeling of these vehicles' characteristics should be accurate except for the accuracy and lethality characteristics since they are classified. However, Tankwars is undergoing the testing, not the vehicles.

Tankwars II and Tankwars III gave the exact same event history and statistics for single, nonburst-weapon combat for 1,000 repetitions for each of the scenarios. In fact, they agree in random numbers generated and events happened, scheduled, and canceled.

Next, Tankwars III was run for the multiple-weapon, burst-fire case. Initially, runs were made to check that the burst-fire cycle and the switching between weapons worked, which they did. Next, sets of runs were made for each of the scenarios at 1-, 2-, and 3-km ranges. Each run was a single wave of 1,000 battles. The force was three red vs. three blue IFVs for meeting engagements, six red vs. three blue IFVs for red attacks, and three red vs. six blue IFVs for blue attacks. The simulation used the Hunsfeld terrain model and the cardioid shot distribution model. The lethality and accuracy data used to obtain the results of this section are shown in Tables 1 and 2.

Table 1. Lethality Data Used for Multiple-Weapon, Burst-Fire Runs

Probability of Catastrophic Kill Given a Hit										
			Orientation of Target with Respect to Firer							
Side	Priority	Weapon	0°	30°	60°	90°	120°	150°	180°
Blue	Primary	Auto-Cannon	.50	.60	.70	.80	.90	.95	.975
Blue	Secondary	Missile	.50	.60	.70	.80	.90	.95	.975
Red	Primary	Cannon	.50	.60	.70	.80	.90	.95	.975
Red	Secondary	Missile	.50	.60	.70	.80	.90	.95	.975

Table 2. Accuracy Data Used for Multiple-Weapon, Burst-Fire Runs

			Stationary Firer/ Stationary Target						Stationary Firer/ Moving Target				Moving Firer/ Stationary Target			
			fixed bias (mil)		variable bias (mil)		random error (mil)		fixed bias (mil)		random error (mil)		fixed bias (mil)		random error (mil)	
Side	Priority	Weapon	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
Blue	Primary	Auto-Cannon	.5	.5	.0	.0	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
Blue	Secondary	Missile	.0	.0	.0	.0	.5/r	.5/r	.0	.0	.5/r	.5/r	—	—	—	—
Red	Primary	Cannon	.5	.5	.0	.0	.5	.5	.5	.5	.5	.5	—	—	—	—
Red	Secondary	Missile	.0	.0	.0	.0	.5/r	.5/r	.0	.0	.5/r	.5/r	—	—	—	—

NOTE:
r - range in kilometers.

The first set of these runs had BFVs on each side to check reciprocity. For meeting engagements with the same number of vehicles on each side, one would expect approximately the same win/loss fractions and an exchange ratio of one. For attack scenarios, one would expect approximately the same win fraction, loss fraction, and exchange ratio for the attacker, regardless whether the attacker was red or blue. The results were so, for the 90% confidence intervals of the win/loss fractions overlapped, and the exchange ratios agreed to within 10%. Tables 3 shows the results. The numbers in the parentheses represent confidence intervals.

Table 3. Reciprocity Check Results

Range	Statistic	Scenarios		
		Meeting Engagement	Red Attack	Blue Attack
1,000 m	Blue Win	.423 (.398,.450)	.257 (.235,.281)	.720 (.696,.744)
	Blue Loss	.457 (.431,.484)	.743 (.720,.766)	.275 (.252,.300)
	Draw	.113 (.098,.132)	.000	.001
	All Dead	.007 (.004,.014)	.000	.004
	Exchange Ratio	0.965	1.549	0.634 = 1/1.577
2,000 m	Blue Win	.149 (.131,.169)	.329 (.305,.355)	.557 (.531,.584)
	Blue Loss	.184 (.165,.206)	.578 (.552,.604)	.333 (.309,.359)
	Draw	.667 (.642,.692)	.088 (.074,.105)	.105 (.090,.123)
	All Dead	.000	.005 (.002,.011)	.005 (.002,.011)
	Exchange Ratio	0.945	1.899	0.515 = 1/1.942
3,000 m	Blue Win	.052 (.042,.066)	.319 (.295,.345)	.589 (.563,.615)
	Blue Loss	.056 (.045,.070)	.569 (.543,.596)	.280 (.257,.305)
	Draw	.892 (.875,.908)	.104 (.089,.122)	.130 (.113,.149)
	All Dead	.000	.008 (.004,.015)	.001
	Exchange Ratio	0.982	1.927	0.564 = 1/1.773

Finally, a set of runs was made to show that the vehicle with multiple weapons would perform better than vehicles with only a single weapon. This set of runs was done with the red side having a missile and cannon weapons while the blue side had either both a missile and cannon, just a cannon, or just a missile system. The blue win fraction and exchange ratio should improve with an increase of weapons, and the results tend to show this. Table 4 shows results for the blue attack scenario. The numbers for the blue attack are as expected.

Table 4. Multiple vs. Single Weapon Results for Blue Attack

Range	Statistic	Blue Armament		
		Cannon and Missile	Cannon	Missile
1,000 m	Blue Win	.977 (.968,.985)	.943 (.930,.955)	.075 (.062,.091)
	Blue Loss	.019 (.013,.029)	.026 (.019,.037)	.246 (.224,.270)
	Draw	.004	.029 (.021,.040)	.679 (.654,.704)
	All Dead	.000	.002	.000
	Exchange Ratio	1.287	1.247	0.324
2,000 m	Blue Win	.887 (.870,.903)	.877 (.859,.894)	.084 (.071,.101)
	Blue Loss	.010 (.006,.018)	.033 (.025,.045)	.328 (.304,.354)
	Draw	.103 (.088,.121)	.090 (.076,.107)	.588 (.562,.614)
	All Dead	.000	.000	.000
	Exchange Ratio	1.297	1.258	0.308
3,000 m	Blue Win	.876 (.858,.893)	.836 (.816,.855)	.076 (.063,.092)
	Blue Loss	.017 (.011,.026)	.042 (.033,.055)	.443 (.417,.470)
	Draw	.107 (.092,.125)	.121 (.105,.140)	.481 (.455,.508)
	All Dead	.000	.001	.000
	Exchange Ratio	1.311	1.250	0.244

Table 5 lists the multiple vs. single weapon results for the red attack.

Table 5. Multiple vs. Single Weapon Results for Red Attack

Range	Statistic	Blue Armament		
		Cannon and Missile	Cannon	Missile
1,000 m	Blue Win	.536 (.510,.563)	.184 (.165,.206)	.021 (.015,.031)
	Blue Loss	.152 (.134,.173)	.333 (.309,.359)	.090 (.076,.107)
	Draw	.302 (.279,.327)	.481 (.455,.508)	.889 (.872,.905)
	All Dead	.010 (.006,.018)	.002	.000
	Exchange Ratio	3.130	2.045	1.999
2,000 m	Blue Win	.331 (.307,.357)	.075 (.062,.091)	.019 (.013,.029)
	Blue Loss	.124 (.108,.143)	.531 (.505,.558)	.056 (.045,.070)
	Draw	.542 (.516,.569)	.393 (.368,.420)	.925 (.910,.939)
	All Dead	.003	.001	.000
	Exchange Ratio	3.229	1.294	2.819
3,000 m	Blue Win	.375 (.350,.401)	.099 (.084,.117)	.013 (.008,.021)
	Blue Loss	.148 (.130,.168)	.494 (.468,.521)	.060 (.049,.075)
	Draw	.475 (.449,.502)	.405 (.380,.432)	.927 (.912,.940)
	All Dead	.002	.002	.000
	Exchange Ratio	3.080	1.414	2.634

In the case of red attack, we observe the counter-intuitive results that the blue loss ratio is higher when the blue army has two weapons than when it has only missiles. The reason is that in Tankwars, an army must be annihilated to be counted as a loss. If an army is overrun, it is counted as a draw. When the defensive blue army has only missiles, it is less likely that they will be detected. In this case, annihilation of blue does not occur. While the blue army may be overrun, these situations are not counted as losses.

Table 6 is the multiple vs. single weapon results for the meeting engagement.

Table 6. Multiple vs. Single Weapon Results for Meeting Engagement

Range	Statistic	Blue Armament		
		Cannon and Missile	Cannon	Missile
1,000 m	Blue Win	.784 (.762,.806)	.521 (.495,.548)	.604 (.578,.630)
	Blue Loss	.055 (.044,.069)	.066 (.054,.081)	.152 (.134,.173)
	Draw	.150 (.132,.171)	.404 (.379,.431)	.244 (.222,.268)
	All Dead	.011 (.007,.019)	.009 (.005,.016)	.000
	Exchange Ratio	2.220	1.702	1.327
2,000 m	Blue Win	.174 (.155,.196)	.000	.184 (.165,.206)
	Blue Loss	.035 (.026,.047)	.000	.029 (.021,.040)
	Draw	.791 (.769,.812)	1.000	.787 (.765,.809)
	All Dead	.000	.000	.000
	Exchange Ratio	1.398	0.000	1.477
3,000 m	Blue Win	.009 (.005,.016)	.000	.010 (.006,.018)
	Blue Loss	.000	.000	.000
	Draw	.991 (.985,.996)	1.000	.990 (.984,.995)
	All Dead	.000	.000	.000
	Exchange Ratio	1.806	0.000	1.826

For the cannon-only case in the meeting engagement at 2 and 3 km, hardly any combat is taking place since the cannon is out of range. Since the automatic cannon is not being used and blue is in hull defilade, the red army can barely detect the blue systems (for the given input data). At 2 and 3 km, there would be no difference in the results between the cannon and missile and missile-only cases since the cannon is not used. However, the starting random seed is different; thus, a small difference in the results does exist.

This sums the results from the given input data set. Some of the other data sets tend to show worse results with multiple weapons than with a single weapon. The primary weapon having poorer performance than the secondary weapon accounts for most of these unexpected results. Performance factors are probability of kill given a shot, range window, time to fire, capability to fire on the move, and ammunition load.

In summary, the results of Tankwars II and Tankwars III in single-weapon, nonburst combat are equivalent. For identical forces on each side, Tankwars III results show reciprocity. Finally, except for certain cases, which have been explained, a side does better with two weapons than with just one weapon. These results verify the latest modifications of Tankwars.

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